1968

The stimulus and memory in concept identification

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THE STIMULUS AND MEMORY

IN CONCEPT IDENTIFICATION

by

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A THESIS

Presented to the Graduate Faculty

of Lehigh University

in Candidacy for the Degree of

Master of Science

Lehigh University

1968

This Thesis is accepted and approved in partial fulfillment of the requirements for the degree of Master of Science

May 24, 1968
(date)

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Abstract: The stimulus and memory
in concept identification

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It was thought that the size and/or type of stimulus array might affect error performance or amount of memory in concept identification. Forty-eight Ss were divided into four groups with each group working with just one size and type of stimulus. The small stimuli were two inches in diameter the large 15 inches. Ss were about 36 inches away from a scheen on which the stimuli were projected. There were two types of stimuli: compact and distributed. The compact contained two diminsions within each figure while the distributed had a separate figure for each diminsion. Both types of stimuli were made up of six binary diminsions and each S was asked to solve 12 two choice discrimination problems in which only one of the diminsions was relevant for any single problem.

An analysis of the error performance to solution indicated that neither stimulus type or size had any significant affect. However, there was some indication that on the first several problems presented to each S that it was more difficult to solve problems with distributed stimuli than with compact.

Memory was measured by observing the probability of immediately solving a problem following an error on the second trial of the information splits. An information split is a way of numerically expressing the amount of

information relevant to problem solution which is presented in any two trial sequence. In contrast to the predictions of the Bower and Trabasso no-memory model it was found that the probability of immediately solving a problem was related to the amount of information just previously presented. When all experimental groups were combined the more information the higher the probability of solution.

A plot and analysis of the backward learning curve revealed that prior to solution Ss had a better than chance probability of making a correct response. This was particularly evident in the few trials just before solution.

There is then some indication that S tests more than one of the possible problem solutions at a time, that once a response based upon a possible solution has been called incorrect there is a decreased probability of again trying that solution, and that S must have some memory of the information presented in previous trials.

INTRODUCTION

Any category of things may be called a concept (Bourne, 1966). Usually these things are perceptable and S must rely upon his senses to group stimuli into categories or concepts. Before S can make inferences from a stimulus presentation and solve a problem in concept identification, he must be able to correctly perceive the immediately available information, and he may retain some information from previous stimulus presentations. This experiment investigates the role of the stimulus and memory in concept identification. Several two choice discriminations were constructed using stimuli with six binary dimensions.

The geometric designs often used as stimulus materials may be described as compact or distributed. Compact stimulus types contain more than one stimulus attribute or dimension within one figure, (for example, a small, black, triangle). Distributed types spread the attributes over separate figures, (for example, a small figure, a black figure, and a triangular figure). With compact stimuli more than one attribute may be perceived in a single glance and this may make the problems easier for S. It is then not necessary to scan a series of figures to see all attributes. However, Kohler and Adams (1958) suggest that "...learning is at least as much a matter of perceptual articulation as of large scale organization." Articulation refers to the ability or process of abstracting out the various stimulus attributes from the entire stimulus pattern. With some compact stimuli, articulation may well be more difficult. Attention may not be as often directed toward some stimulus attributes and possible solutions or hypotheses based upon some attributes may not as often be tested. Distributed stimuli separate the attributes and tend to make it less likely that S would not notice and test each attribute.

Previous investigations of this problem have confounded stimulus type with the size of the stimulus. Shepard, Howland and Jenkins (1961) constructed problems with identical solutions but different types of stimuli. The use of compact stimulus types tended to facilitate performance, but unfortunately the distributed patterns were made up of three figures of the same size as the single compact figure. The distributed stimulus arrays were then about three times as large as the compact. The increase in scanning required by the distributed stimuli may account for the relative difficulty of solving problems made up of these stimuli. Bourne (1966) feels that this "...tends to force S to deal with the attributes individually..." and this may well affect performance by limiting the number of hypotheses tested at a time. Loughlin (1965

1966) compared concept attainment performance using compact geometric forms to performance using displays consisting of combinations of six plus and/or minus signs in different colors in a row. No significant differences in number of trials to solution were found, but the use of different stimulus attributes makes a valid comparison difficult.

Shepard et. al. also observed that Ss have difficulty in translating distributed stimuli into words, and they hypothesized that this may make memory of previous stimulus presentations more difficult. A Compact stimulus may be verbalized as "a small white circle" while the corresponding description of a distributed stimulus would be "figure one small, figure two white, figure three circle." The sheer length of this verbal description may then make distributed stimuli more difficult to remember. The results of studies by Cahill and Hovland (1960) and Bourne, Goldstein and Link (1964) indicate that the larger the number of previous stimulus presentations available to S, the better the overall performance. Memory of previous presentations may then facilitate performance.

If compact stimuli are easier to remember, then performance should be facilitated and memory should be better when they are used. However, if Ss have difficulty articulating out the stimulus attributes from compact stimuli, performance may be hindered. If larger stimuli increase the perceptual scanning requirements, then performance should be facilitated when smaller stimuli are used.

Bower and Trabasso (1963a) using compact stimuli have developed a no-memory mathematical model for concept identification, and Trabasso and Bower (1964) have developed a limited memory model. The no-memory model assumes that on any trial S's response is based upon one hypothesis which is dependent upon one stimulus attribute, (for example: Response one for large, response two for small.) If that is called correct, S continues to respond on the basis of that hypothesis. If the choice is called wrong, S resamples at random from the entire set of hypotheses.

Sampling with replacement involves no memory. Only following an error can S enter into the solution state, and the probability of making the switch to the solution state is the same following any error. As such a switch is the last error, the probability of being correct of any trial preceding the last error would remain stationary at the chance level. The predictions of the limited memory model are similar with the exception that S remembers some of the information contained in this current working hypothesis.

Richter (1965) has suggested a direct method for measuring the effect that memory of past events has upon the probability of problem solution. Bower and Trabasso (1963a, 1963b) and Trabasso and Bower (1964) used data averaged over random stimulus sequences. Richter demonstrated that sequences had a powerful effect upon the probability of solution. Ideally one could consider all possible stimulus sequences, but this appears at best to be impractical. With six binary dimensions, the number of two trial sequences alone would exceed 4,000. Richter proposed that this total may be reduced if one assumes that it is not the specific stimuli but rather the logical relationships between them that are important. The analysis is then not based upon changes of specific stimulus attributes, but on the number of attributes which change from trial to trial.

For example, consider a problem using stimuli having six binary attributes with the size attribute relevant. If on any two-trial sequence the size attribute is the only attribute to change or is the only attribute to stay the same then this attribute has "split off" from the other five irrelevant attributes. Such a two-trial sequence would completely define the problem solution. Richter referred to such two-trial sequences as "1-5 splits." In order of decreasing information about the relevant stimulus attribute there are 1-5, 2-4, 3-3, 4-2, 5-1, and 6-0 splits. This information content classification scheme then reduces the number of types of two trial sequences from over 4,000 to six.

When either all of the attributes or none of the attributes change from trial n to trial n + 1 no information helpful to problem solution is available yet the Bower and Trabasso no memory model predicts that the probability of starting a criterion run following an error on the second trial of such "no information" splits would be the same as the probability following a "solution" split when the relevant attribute has split off from the irrelevant attributes. However, if S retains some information from the previous trial then the probability of starting a criterion run following an error on the second trial of "solution" splits should be greater than following "no information" splits. The more information available on any two trial sequence the higher the probability of solution following that sequence.

It seems reasonable to assume that memory should facilitate problem solving. The better the memory of previous stimulus presentation the more information can be logically gained from the then present stimulus presentation. There then may be an interaction between the stimulus and the amount of memory evident. If a stimulus type or size facilitates or inhibits memory, then this should be reflected in differences in the probability of solution following an error on the second trial of the various splits. Differences in the number of errors to solution then may also be taken as an indication of differences in the memory requirements for different sizes and types of stimuli.

Method

<u>Design</u>. The design was a 2x2x12 with repeated measures on the last factor. Represented were two stimulus types (distributed and compact,) two stimulus sizes (large and small) and the 12 problems given to each <u>S</u>. Each <u>S</u> was tested with only one stimulus type and size. Twelve <u>S</u>s were assigned to each of the four experimental groups.

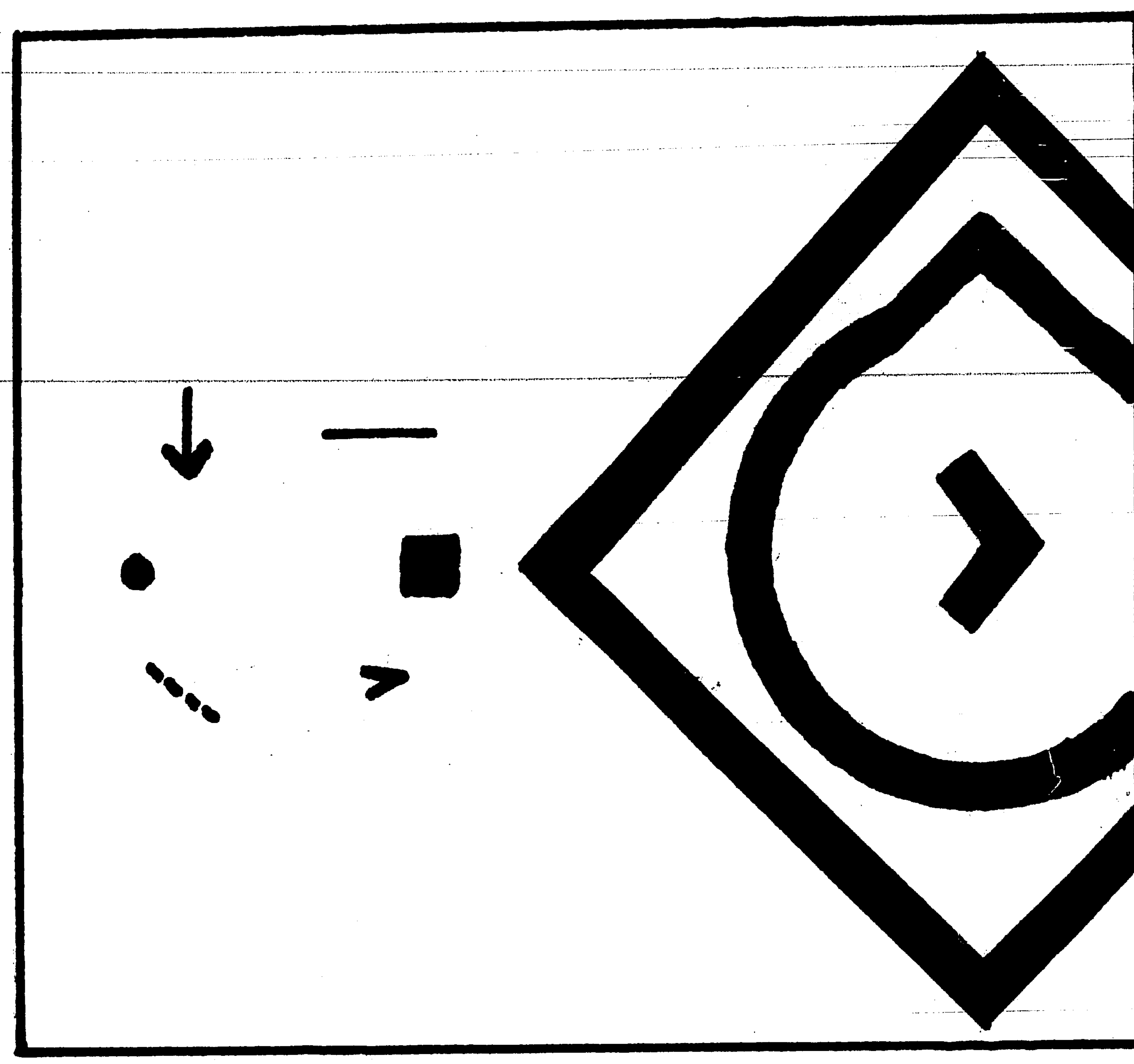
<u>Subjects</u>. The <u>S</u>s were 53 men and women from undergraduate summer classes at Lehigh University and Moravian College. <u>S</u>s were assigned to the four experimental groups in their order of appearance. Before testing, each <u>S</u> was asked to read nine letters $\frac{1}{4}$ inch high, printed on a card held just in fromt of the projection screen. On <u>S</u> was dropped for failure to verbalize all nine letters correctly, and four <u>S</u>s were eliminated for failure to understand the instructions or because of equipment problems. Forty-eight <u>S</u>s then completed testing.

<u>Stimuli</u>. Both compact and distributed types of stimuli were geometric designs as shown in Figure 1. The dimensions and values were: type of line (solid or dashed), orientation of rectangle (square or diamond), size of circle (large or small), direction of the point (up or down), length of line (long or short), and size of angle (large or small).

Insert Figure 1 about here

The size of the stimulus was controlled by the distance between projector and screen. Small stimuli were two inches

Fig. 1 Example of the stimulus types and their relative sizes. On the left is a small distributed stimulus, on the right a portion of a large compact stimulus. The actual stimuli were white on a black background.



in diameter, the large 15 inches. The designs were photographed with high contrast 35 mm. film and mounted in $2\frac{1}{4}$ by $2\frac{1}{4}$ slides which, when projected, produced a white on black image. For each stimulus type 64 slides represented all possible combinations of six attributes with two levels of each. Three sets of 64 slides were made for each stimulus type. Two circular slide trays with an 81 slide capacity were filled with a random sequence of slides for each stimulus type. The remaining 30 slides were used in the practice problem. The same slide sequences were used for all groups. Three equally spaced starting points were designated for each slide tray. From these three starting slides, the projector could be set to go through the slides in either a clockwise or counter-clockwise direction. There are then six possible stimulus sequences for each tray, and one of the 12 solutions was assigned to each stimulus sequence. These sequences of slides made up the 12 problems given to each S. All solutions were based upon single stimulus attributes, with two possible solutions on each attribute. For example, the two solutions based upon the size attribute were response one for large, response two for small and response one for small, response two for large. Twelve different orders of presentation for the problems were also randomly chosen, the only restriction being that in each experimental group each problem must appear once as the first problem and once at the last.

Each S was presented with one of the 12 orders of 12 problems with an S from each of the experimental groups assigned to each of the orders. The first six Ss in each experimental group were treated as explained above. The last six were treated identically with the exception that all problems which had initially been presented with the projector in the clockwise operating position were now s shown counter-clockwise and vice versa. Each of the 12 possible solutions were then tested with two different s sequences of slides.

Procedure and Instructions. Each S was seated behind a table 36 inches deep, the back of which was flush with a wall which separated S's room from the apparatus room. Mounted in this wall was a 18 by 29 inch panel of translucent frosted glass. An image projected on it could be clearly seen from either side. The S's room was dark except for the light which came through the glass.

On the table in front of S was a choice panel with two horizontally mounted, square, white, plexiglass choice buttons. The button chosen in each trial was illuminated as soon as the choice was made. Just above each button was a red signal lamp which came on above the correct choice button as soon as a choice was made. Between and slightly below the choice buttons was a small round reset button which advanced the projector to the next slide.

The instructions explained the nature of the task, the twelve possible hypotheses, the meaning of the red signal lights, and the values of each dimension. It was emphasized that only one hypothesis would allow the subject to make ten correct responses in a row and solve the the problem. The Ss were encouraged to try to solve the problems in as few slide presentations as possible. One practice problem 30 slides long was given. If S did not know the correct solution by the 20th slide, he was reminded that only one of the dimensions was relevant and he was told the problem solution.

The times from stimulus presentation to choice and from the choice to the push of the reset button were controlled by S. The time between stimulus slides was 2.5 seconds, the time between problems about one minute. A problem was considered unsolved if S was unable to make ten correct responses in a row within 81 slides. Only two of the 576 problems were considered unsolved.

If on any one of the problems S made four or more correct responses in a row and then made one error followed by a criterion run, the S was asked what happened on that trial. If S indicated that he had known the correct solution but had pushed the wrong button he was cautioned to avoid such responses but to report it if it again happened. To decrease the probability of incorrect reports, claims were considered valid only if four or more correct responses immediately preceeded such a trial.

The corrected data referred to in the results section is based on the assumption that the trial of last error is the first error immediately preceding the "wrong button" response. Thirty-six such responses were recorded among the 576 problems presented.

Apparatus. An eight channel tape reader and a Kodak 800 carousel projector controlled stimulus presentation while a Friden tape punch was automatically programmed to record for each slide the values of each dimension, the side chosen, if the choice was correct or incorrect, and two times in tenths of seconds; the time between stimulus presentation and choice and between choice and the push of the reset button.

Results

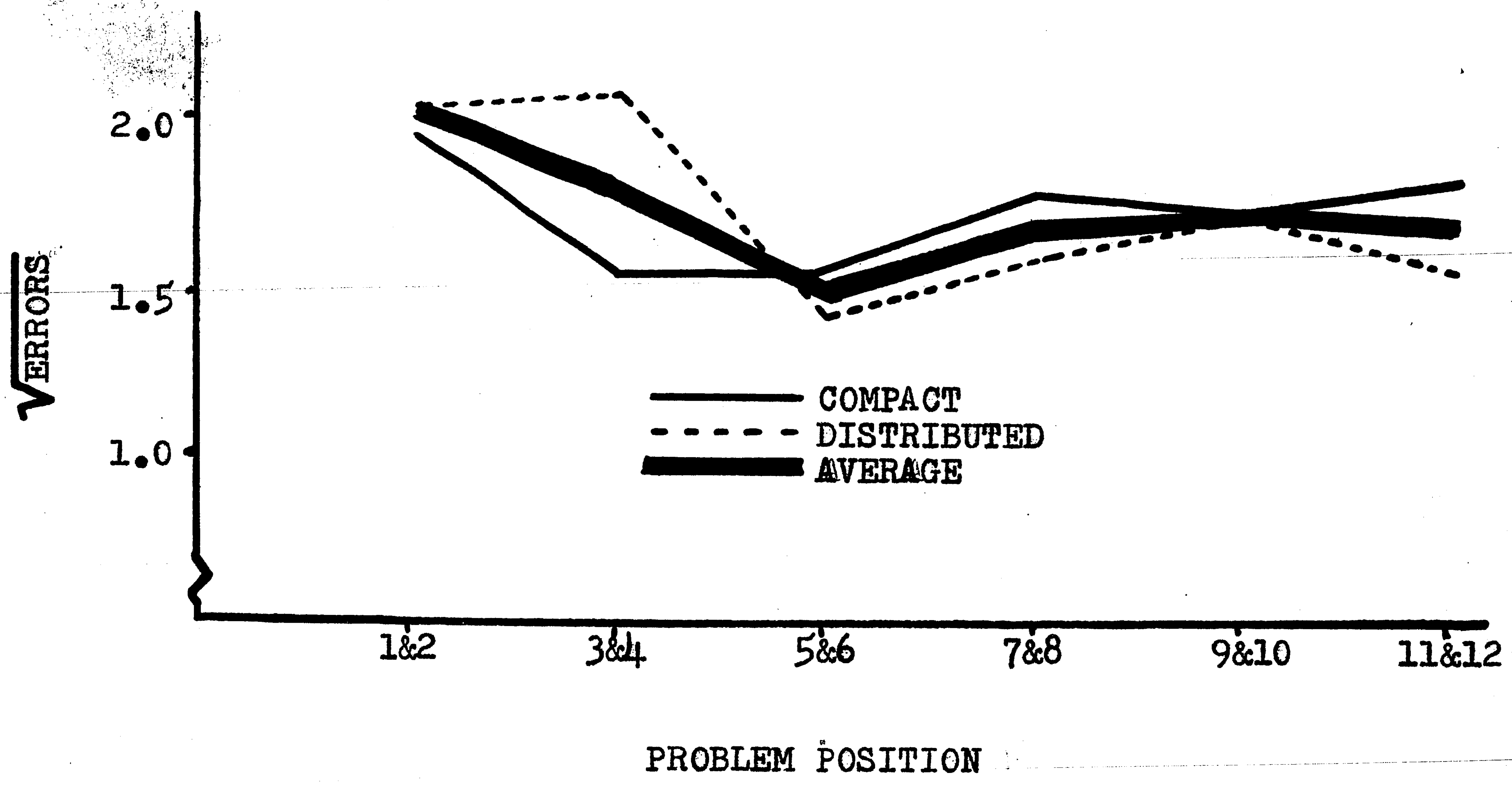
An inspection of a plot of the raw error data revealed a positive skew so a square root transform was performed before analysis. This transformed data was submitted to a 2x2x12 analysis of variance with repeated measures on the last factor (Winer, 1962). A Summary can be seen in Appendix 1. Neither stimulus type nor size was found to significantly influence error performance ($F<1$ in both cases.) Problem position in the series of twelve problems was significant ($F=2.55$, df=11/484, $p<.05$). As is shown in Figure 2, the Ss tended to solve with fewer errors toward the end of the problem series.

Insert Figure 2 about here

The significant problem by stimulus type interaction is also shown in Figure 2($F=1.99$, df=11/484, $p<.05$). Ss presented with distributed stimuli tended to make more errors than compact groups on the problems early in the problem series, while toward the end of the series this relationship was reversed. The significant ($F=23.6$, df=11/484, $p<.05$) three-factor interaction is shown in Appendix 2.

The probability of starting a criterion run following an error on the second trial of all types of two trial sequences is shown in Figure 3 for each experimental group. Using the combined corrected data from all groups an X^2 was run to compare the probabilities of solution

Fig. 2. Square root of number of errors by problem position. Problems have been combined to smooth the curve.


2.0
1.5
1.0
√ERRORS
COMPACT
DISTRIBUTED
AVERAGE
1&2
3&4
5&6
7&8
9&10
11&12
PROBLEM POSITION

using the data from all two trial sequences in which an error was made on the second trial. With all splits from a 1-5 (solution) to a 6-0 (no information) considered, the amount of information in two trial sequences significantly influenced the probability of immediately starting a criterion run (X^2=11.55, p .05 with 5 df.). The direction of this influence seems reasonably clear. The more information contained in a two trial sequence the higher the probability of solution. This influence is particularly noticeable at the extremes of information content.

Insert Figure 3 about here

Several X^2's were run to determine if there were differences between experimental groups in the probability of solution following the various splits. The only value which approached significance was found when the probability of solution following a 1-5 split with compact stimuli was compared with the same probility using distributed stimuli. However, the calculated value of 2.03 is not significant at the .05 level with 1 df.

Experimental groups were then combined to construct the forward and backward learning curves as shown in figures 4 and 5. Both curves were tested for stationarity as suggested by Suppes and Ginsberg (Bower and Trabasso, 1963a). The curves were based upon the corrected data as explained above and include only solved problems. The

Calculated X^2 values for both curves were significant at the .05 levels. Values of 39.36 and 28.07 were found for the forward and backward curves respectively. Neither curve can then be considered stationary about a line representing the over all mean percentage of correct choices. Both curves also reliably represent data in which the probability of a correct response is above a line representing the apparent chance level of .5(X^2= 77.24 forward, 79.08 backward.)

Insert Figures 4 and 5 about here

Fig. 3 Probability of starting a criterion run following an error on the second trial of all possible information splits. The data from 5-1 and 6-0 splits has been combined because of the low number of instances in the individual groups.

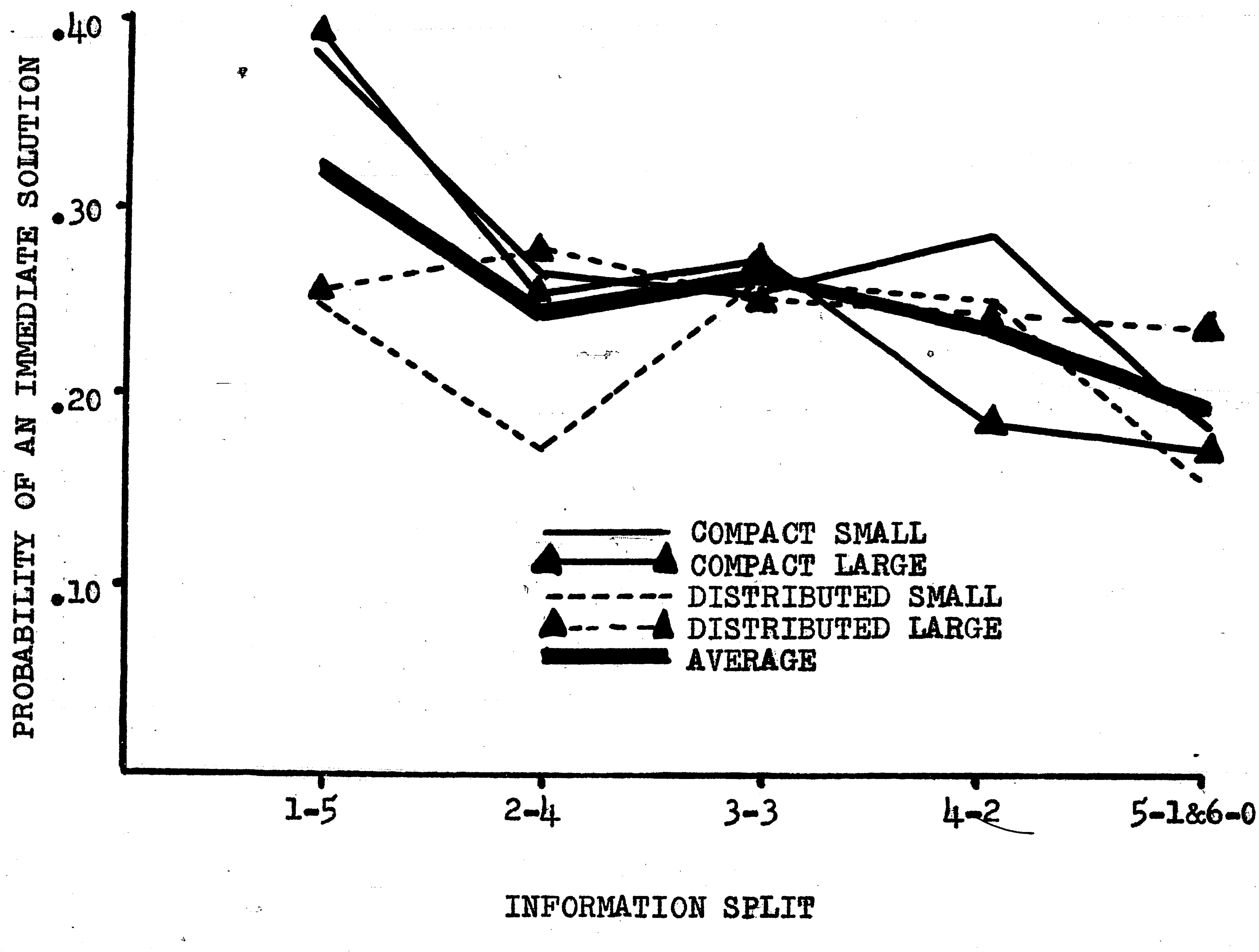

PROBABILITY OF AN IMMEDIATE SOLUTION
.40
.30
.20
.10
COMPACT SMALL
COMPACT LARGE
DISTRIBUTED SMALL
DISTRIBUTED LARGE
AVERAGE
1-5
2-4
3-3
4-2
5-1&6-0
INFORMATION SPLIT

Fig. 4 Forward learning curve for first 12 trials. Dashed line indicates average probability of a correct response on these trials. The solid line represents the assumed chance level.

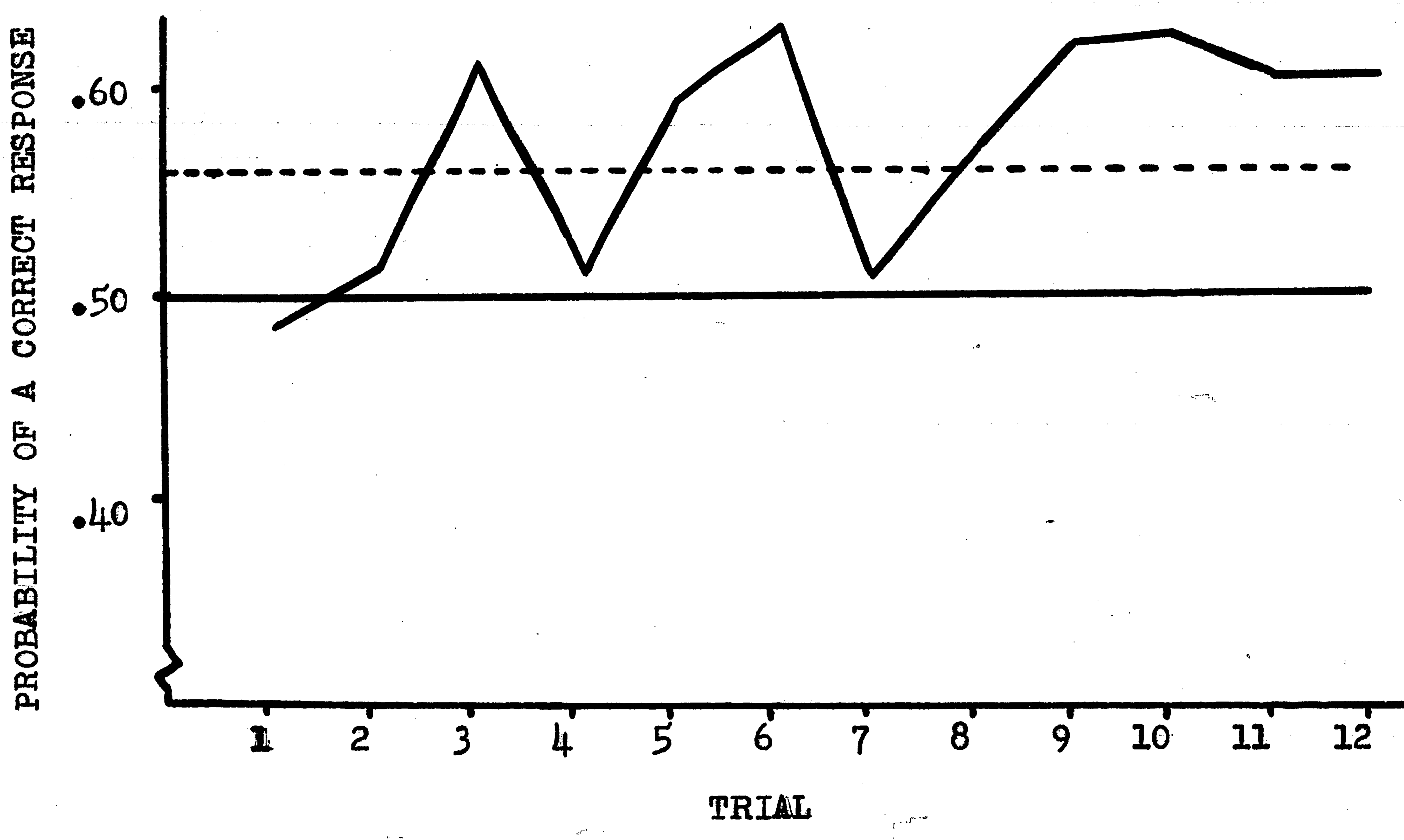
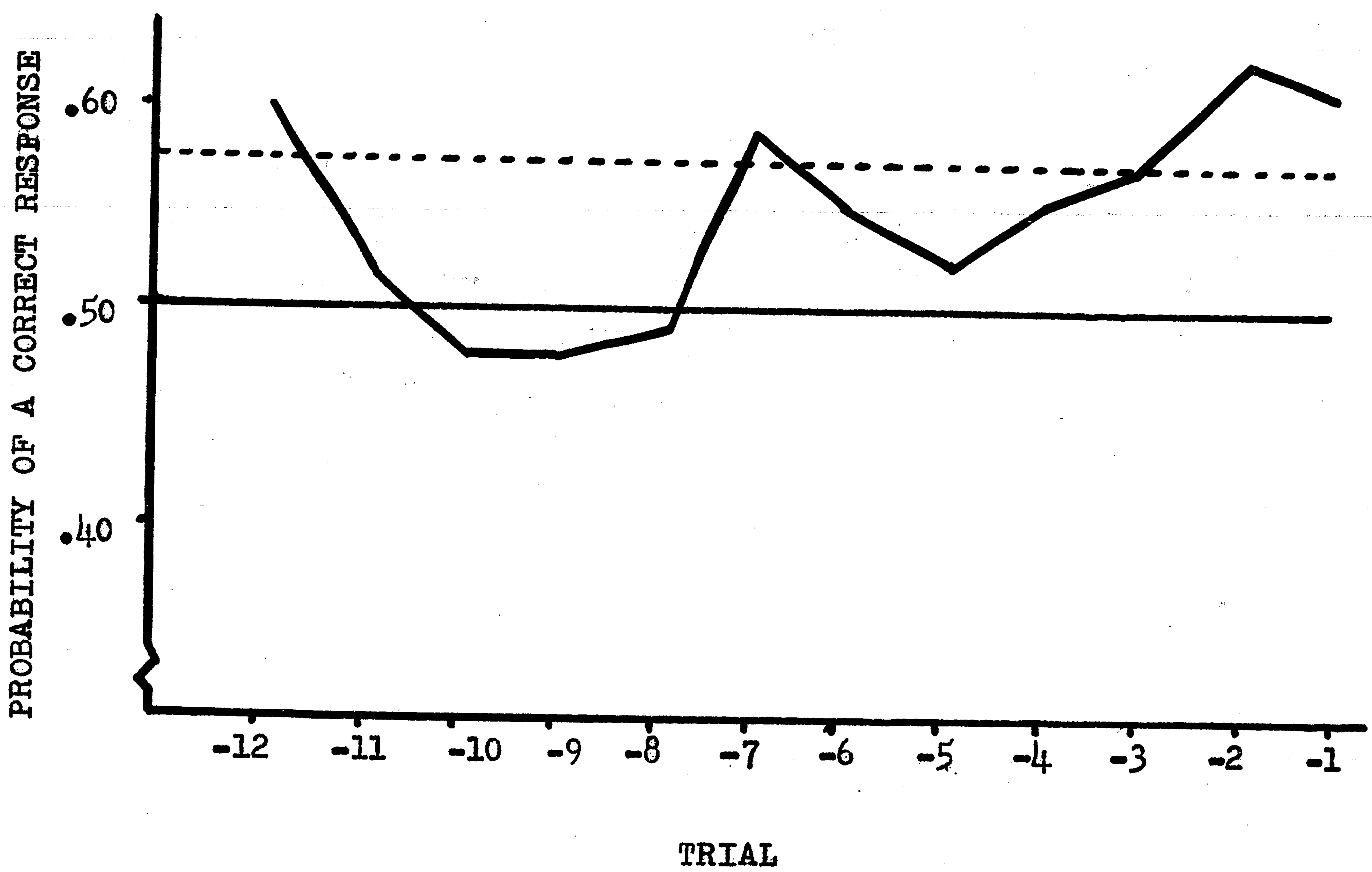

PROBABILITY OF A CORRECT RESPONSE
.60
.50
.40
1
2
3
4
5
6
7
8
9
10
11
12
TRIAL

Fig. 5 Backward learning curve for the 12 trials before the last error. Dashed line indicates average probability of a correct response on these trials. The solid line represents the assumed chance level.


PROBABILITY OF A CORRECT RESPONSE
.60
.50
.40
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
TRIAL

Discussion

Performance as measured by number of errors to solution was not significantly influenced by either stimulus type or size. This result may not, however, be interpreted as a denial of the importance of articulation in concept formation experiments. The stimuli described as compact by Shepard, Hovland and Jenkins (1961) may be more accurately described as unitary. One single figure, for example a large, black circle, contained all attributes. The stimuli used in this experiment may be called compact because more than one attribute was represented in each figure and two of the figures were surrounded by the third figure, but these were not single unitary stimuli. Articulation may be more of a problem with single unitary stimuli or they may be easier to work with because of the ease of coding. The compact stimuli used in this experiment may well be more difficult to verbally describe than the unitary stimuli used by Shepard et al. (1961) and this may account for the failure to find significant differences in error performance.

From previous work in this laboratory a practice effect was not unexpected, but the reasons for this remain unclear. It may be some form of a learning to learn phenomenon or the development of mediating process. Familiarity with the experimental situation and stimuli may also be of importance, but informal observation by E indicates that at least some S's develop efficient verbal methods for coding the stimuli which may facilitate performance. Such a process may also account for the interaction between stimulus type and problem position. Early in problem series S may find it difficult to code the distributed stimuli, but with practice coding may become easier and the number of errors to solution are reduced. This lends partial support for the original hypothesis which suggested that difficulty in coding may make it more difficult to solve problems made up of distributed stimuli. The in error performance between stimulus types is most evident in the first several problems (Figure 2) and as most investigators present each S with a small number of problems this effect may be of interest.

The three-factor interaction is graphed in Appendix 2 but there is no readily apparent explanation for the significant effect.

The explicit instructions which restricted the hypotheses likely to be tested to those which could lead to solution and the pretraining which served to familiarize all Ss with the attributes and the procedure may account for the lack of significant differences in error performance between experimental groups. The pretraining and large number of problems given to each S may be responsible for the many differences between this data and that typically reported by Bower and Trabasso.

Clearly several of their theoretical assumptions are not supported. Trabasso plotted both forward and backward learning curves based upon problems similiar to those used in this study. For both Trabasso curves the percentage of correct responses across trials remained stationary as measured by the Suppes and Ginsberg χ^2 and none of the plotted points differed significantly from the a priori chance level of .50. (Bower and Trabasso, 1963a).

The backward learning curve derived from this data differs from that plotted by Trabasso in three ways: 1) A χ^2 indicates that this data is not stationary, 2) eight of the 11 plotted points are above the assumed chance level and 3) there is a tendency for the percentage of correct responses to increase as the final error is approached. Stationarity is predicted from the all-or-none assumption within the no-memory model. As S tests only one solution or hypothesis at a time and continues to test that solution until an eeror is called, the probability of being correct on any trial prior to the start of the criterion run should remain at the chance level. The results of this experiment suggest that S does not simply test one hypothesis at a time and then resample with replacement if an error is called. The fact that both forward and backward curves are above the assumed chance level indicates that S must sample more than one hypothesis at least some of the time, and the rise in the backward curve is accounted for if one assumes that once hypotheses are sampled and responses based upon them called incorrect there is a diminished probability that they will again be sampled.

If S samples more than one hypothesis and if in that sample the relevant hypothesis is included, the probability of a correct choice on the second on any two consecutive trials on which the same hypotheses are sampled will be above the chance level. If, for example, on trial n S bases his response upon two hypotheses including the correct one and is called correct, there is a higher than chance probability that he will be correct on trial n + 1. If both stimulus attributes on which the hypotheses are based change or if both stay the same then S need only to continue to base his response upon these hypotheses and he will be correct. In a random stimulus sequence the probability of any two chosen attributes changing from one trial to the next is .25. There is the same probability that both will stay the same so on half of the possible two trial splits S will always be called correct. The other half of the time one of the a attributes will change from trial n to trial n + 1. In these instances S's response may be based upon only one of the hypotheses considered. The response will then be correct 50% of the time as long as the probability of choosing between hypotheses is equal. So, if the relevant or correct hypothesis is one of two sampled on any two trial sequence, the probability that S will be correct on trial n + 1 is .75.

It is, of course, unlikely that many Ss perform just as described above. A S may well test more than two hypotheses at a time. The more hypotheses tested on any t trial the more likely it will be that the correct hypothesis will be tested and therefore the more likely that a correct response will be made. The testing of more than one hypothesis at a time is adequate to account for the higher than chance level performance but what of the rise in the backward curve as solution is approached? This may be adequately explained if the probability of including the correct hypothesis among those tested has a tendency to go up the closer S is to solution or if the probability of sampling the correct hypothesis remains the same while the probability of resampling an incorrect hypothesis is diminished. If the probability of resampling an incorrect hypothesis is diminished once a response based upon it has been called incorrect then there is an increasing probability over trials that the correct hypothesis will be among those sampled.

If S is testing more than one hypothesis at a time and if there is a lower probability of resampling a hypothesis once it has been shown to be incorrect then S must base his responses at least in part upon information from previous trials, and the probability of entering a solution state on a given trial should be related to the amount of information previously presented. This was found to be the case when the information content of all two trial sequences in which an error appeared on the second trial was considered. When all information splits from the 5-1 (solution) split to the 6-0 (no information) split were tested the type of split was found to significantly influence the probability of solution. This is consistant with the data reported by Richter (1965) and a again it appears clear that the higher the information content of a two trial sequence the greater the probability of immediately entering into the solution state. Contrary to the original Bower and Trabasso model the probability of starting a criterion run is not the same following any error, and the difference can only be accounted for if it is assumed that Ss retain some information from previous stimulus presentations.

From these data is is then possible to suggest that S tests more than one of the possible problem solutions at a time, that once a response based upon a possible solution has been called incorrect there is a drecreased probability of again sampling that solution, and that S must have some memory of the information presented on previous trials.

APPENDIX I

Analysis of Variance: $\sqrt{\text{Errors}}$

TABLE 1

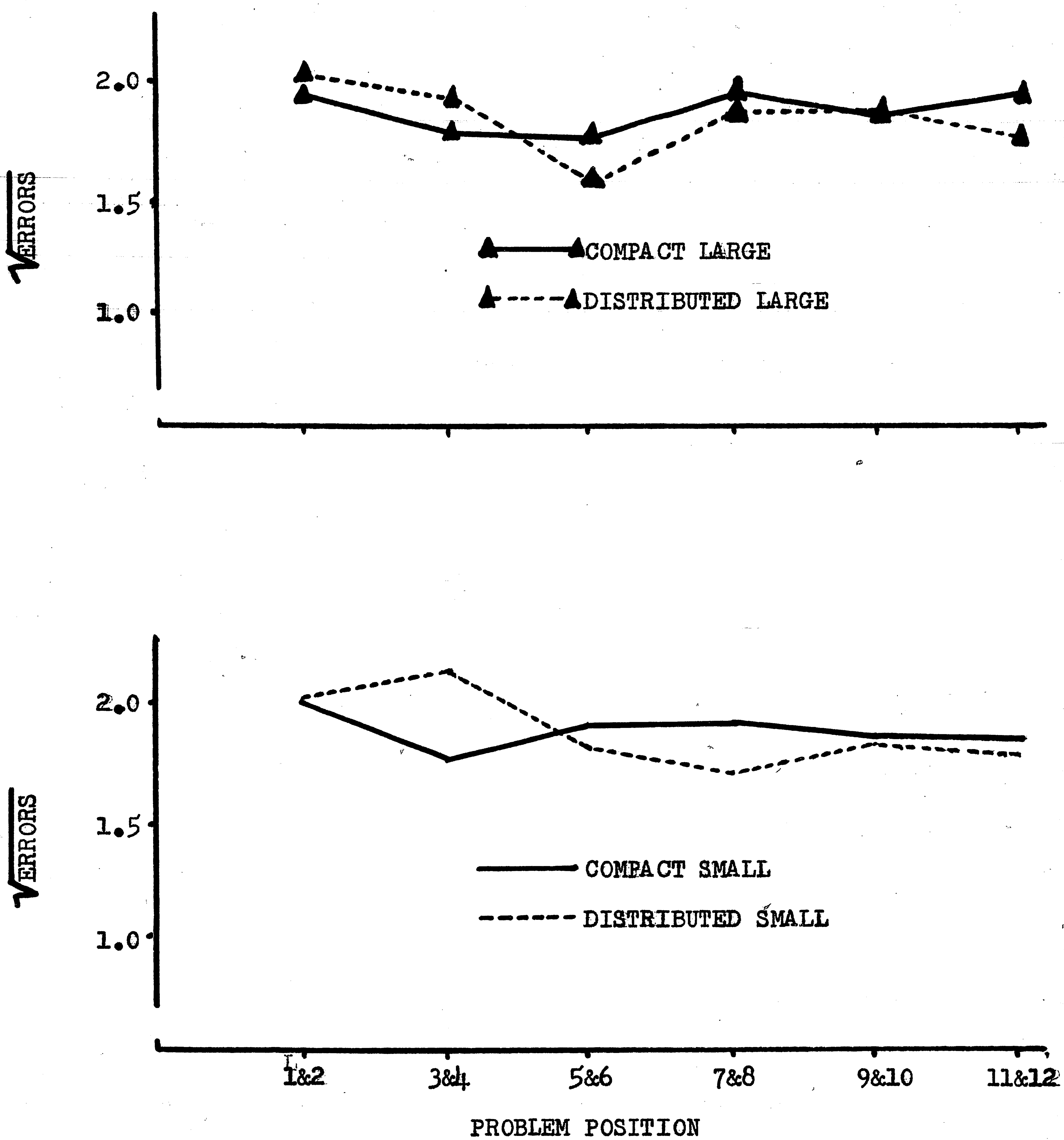
Analysis of Variance: $\sqrt{\text{Errors}}$

Source	df	MS	F
Between Ss	47	[illegible]	
Stimulus Type (A)	1	.0633	< 1
Stimulus Size (B)	1	.1196	< 1
A X B	1	.3099	< 1
Error within groups			< 1
between Ss	44	.8735	< 1
Within Ss	528		
Problem Position (C)	11	1.8294	2.55 #
A X C	11	1.4289	1.99 #
B X C	11	.9447	1.31
A X B X C	11	16.9615	23.60 #
Error within groups within Ss	484	.7188	

# $P < .05$

APPENDIX 2

Fig. 6 The three-factor interaction


2.0
1.5
1.0
√ERRORS
COMPACT LARGE
DISTRIBUTED LARGE
2.0
1.5
1.0
√ERRORS
COMPACT SMALL
DISTRIBUTED SMALL
1&2
3&4
5&6
7&8
9&10
11&12
PROBLEM POSITION

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Vita

The author was born October 23, 1940 in Detroit, Michigan. The parents, Dr. Raymond H. and Naomi I. Hobrock, resided with the author in Birmingham, Michigan a small town 20 miles north of Detroit. After graduating from public high school in 1959, Mr.Hobrock attended Kenyon College and recieved the A. B. degree with a major in psychology in June of 1963. He married shortly after graduation and for two years worked in labor relations with the Ford Motor Company in Dearborn, Michigan before starting graduate work in psychology at Lehigh University.